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Title: Use of Wetlands in the Tulare Lake Basin by Wintering Ducks.

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I evaluated the use of various wetlands by wintering ducks in the Tulare Lake Basin (TLB), California, during October 1982 - April 1983 and September 1983 - March 1984. Aerial waterfowl counts of the TLB were used to document spacial use patterns by ducks. Ground surveys on evaporation ponds in the Tulare Lake Drainage District (TLDD) were used to evaluate duck use of specific ponds with varying chemical and biological parameters. During mid-winter, up to 300,000 ducks used the TLB. The most abundant species (northern pintail (*Anas acuta*), northern shoveler (*Anas clypeata*), and green-winged teal (*Anas crecca*)) were found on freshwater habitats. Ruddy ducks (*Oxyura jamaicensis*) were the only species to extensively use the evaporation ponds. With the exception of ruddy ducks, the evaporation ponds did not appear to be valuable for feeding areas, but provided sanctuary during the hunting season. The use of evaporation ponds by waterfowl may be heavier in years without the extensive floodwater that was present during this study.

Use of Wetlands in the Tulare Lake Basin by Wintering Ducks

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USE OF WETLANDS IN THE TULARE LAKE BASIN BY WINTERING DUCKS

I. INTRODUCTION

Preservation and enhancement of wetland habitat is vital for the conservation of waterfowl (Sanderson 1976). Loss of wetlands due to drainage and degradation creates an ever declining habitat base for waterfowl (Studholme and Sterling 1964, Tiner 1984), necessitating enhancement and restoration of remaining wetlands (Bellrose and Low 1978). Loss and degradation of wetlands on wintering areas has been extensive (Studholme and Sterling 1964, Aus 1969, Gilmer et al. 1982, Tiner 1984). The quantity and quality of wetlands on wintering areas are important to survival and maintenance of wintering waterfowl and successful reproduction on the breeding grounds (Shannon 1965, Chabreck 1979, Heitmeyer and Fredrickson 1981). The requirements of wintering ducks are an important consideration in developing management plans on wintering areas (Fredrickson and Drobney 1979).

The San Joaquin Valley (SJV) in California historically has been important to wintering waterfowl in the Pacific Flyway. The SJV has changed dramatically from its original condition, perhaps to a greater extent than any other area in North America. Natural wetlands covered over 253,000 ha prior to 1900 (U. S. Fish and Wildlife Service 1978), mostly in the Tulare Lake Basin (TLB). After 1945, flood control and water storage dams were constructed to divert water that once sustained these wetlands. In less than 100 years, most of the historic wetlands were converted to other land uses, especially agricultural production. Nearly all surface water was diverted for irrigation and domestic needs and ground water supplies have been seriously depleted. The last large parcel of waterfowl habitat lost in recent years included the Tulare and Buena Vista Lake basins in the southern end of the SJV (Chattin 1964). Today the TLB contains less than 6,000 ha of wetlands (Euliss 1989). Remaining wetlands in the area include Kern National Wildlife Refuge (NWR) (up to 1,300 ha), private duck clubs (up to 1,300 ha), evaporation ponds (1,165 ha), a lake (120 ha), a municipal oxidation pond (160 ha), and irrigated fields (up to 1,200 ha). Management of the remaining wetlands is expensive due to the high cost of water. Pumping ground water has become prohibitively expensive and wetlands have low priority for water supplies from purchased water sources (Gilmer et al. 1982).

Soils in the TLB are saline and many farmers are installing subsurface drainage systems to leach toxic salts from agricultural fields. Poor water quality of drainwater precludes discharging into natural waterways. Disposal of the drainwater is difficult in the hydrologically closed basin, and the only means of disposing drainwater in the TLB is by evaporation in shallow (< 1m) ponds. As much as 1 ha of evaporation pond may be required for every 5 ha of drained land, posing major disposal problems for agricultural interests (San Joaquin Valley Interagency Drainage Program 1979, Hanson 1982). Originally agricultural drainwater was thought to have potential for wetland management (Ives et al. 1977); however, high concentrations of selenium have been found in these evaporation ponds (Presser and Barnes 1985) and they may pose health risks for wildlife (Ohlendorf et al. 1986a, 1986b, 1987).

During the time frame of my project, a major effort was underway by the U. S. Fish and Wildlife Service to determine the value of evaporation ponds as habitat for waterfowl. The goal of my study was to evaluate duck use and selection of wetland habitats, including evaporation ponds, in the TLB. The specific objectives were to determine preference by waterfowl for 5 types of wetlands in the TLB and to evaluate the affect of salinity regimes and macroinvertebrate communities on use of evaporation ponds by several species of waterfowl.

II. STUDY AREA

The TLB (13,000 km^2) forms the southern end of the SJV, California (U. S. Fish and Wildlife Service 1978). The topography is flat and the basin is extensively diked and dissected by numerous canals that deliver irrigation water. Summers are hot and dry with winter temperatures rarely falling below 0°C but fog is often persistent during winter. Precipitation averages 15 cm annually. Large scale irrigation of agriculture fields (fields of 256 ha) produces a variety of crops, including cotton, barley, safflower, and alfalfa.

For this study wetlands in the TLB were divided into five types: duck clubs, evaporation ponds, irrigated agricultural fields, an oxidation pond, and freshwater marshes. Private duck clubs covered about 1,080 ha in the winter of 1982-83 and 1,300 ha in 1983-84. There were 18 evaporation ponds averaging 65 ha in size (1,165 ha total). Fields flooded prior to planting (irrigated fields) made up 1,210 ha in 1982-83 and 950 ha in 1983-84. The Bakersfield oxidation pond, a waste treatment plant, covered about 160 ha. Freshwater marshes included the Kern and Pixley NWRs (120 to 1,925 ha); Woollomes Lake, a recreational lake (120 ha); and 4,980 - 43,470 ha of floodwater in the basin. Unusually large amounts of floodwater were present both years due to heavy rains in 1982.

Evaporation ponds were shallow with sloping sides and flat bottoms, to facilitate evaporation. The evaporation ponds in Tulare Lake Drainage District (TLDD), Kings and Kern counties, California, have been in use continuously since January 1980. The ponds were 5 km apart, in 3 series, each containing 4 or 10 connected cells (18 ponds total). Water movement was unidirectional in the ponds and because of progressive evaporation, salinity increased from cell to cell within each series. The salt load entering a series of evaporation ponds was approximately 5,000 - 10,000 umhos/cm^2 electrical conductivity (EC), but increased in successive ponds and exceeded 300,000 umhos/cm^2 EC in terminal ponds. By comparison, seawater is 54,000 umhos/cm^2 EC at 25°C.

The area around the evaporation ponds was barren, supporting only sparse terrestrial vegetation. Diversity of organisms in the ponds was low and aquatic plants were restricted to a few small patches (about 100 ha of the 1,165 ha of this wetland) (Euliss 1989).

III. METHODS

Tulare Lake Basin

Aerial counts of waterfowl in the TLB were conducted approximately monthly by the U.S. Fish and Wildlife Service (USFWS) from October 1982 - February 1983 and September 1983 - April 1984. Data recorded included the number of individuals of each species present and the size of each wetland.

Analysis

Johnson's (1980) Prefer test was used to evaluate the relative selection of the wetland habitats in the basin by ducks. Selection of habitats was examined for all species of ducks combined and for northern shovelers (*Anas clypeata*), northern pintails (*Anas acuta*), and green-winged teal (*Anas crecca*), separately. Wetland habitats were categorized in 3 groupings. In the first grouping, wetlands were categorized by ecological differences; the categories were freshwater marshes, evaporation ponds, irrigated fields, and a municipal oxidation pond. The ecological scale grouped freshwater and duck clubs together since both groups were present over long periods and were both freshwater. Irrigated fields were freshwater also but were ephemeral and available to ducks for only brief periods each winter.

The second grouping was based on the primary intended management function of the wetlands: refuges, floodwater, evaporation ponds, duck clubs, and irrigated fields. Refuges and duck clubs were managed to attract ducks, but whereas the refuge functioned in that capacity as long as water was available, the duck clubs were managed for hunting season only. Floodwater was impounded to minimize inundation of agricultural cropland. Irrigated fields were managed for crop production. Two small permanent ponds (an oxidation pond and a recreational lake) were excluded. In the third grouping, the use and relative preference for the 6 areas of floodwater were examined.

Data from both seasons were combined in the analysis of selection. Because some areas were not censused during all aerial surveys, sample sizes for analysis of selection varied. Four or 5 surveys from 1982-83 and 6 or 7 from 1983-84 were used in the analysis depending on the habitats being examined. Selection analyses were performed on a microcomputer with the program PREFER87 (Frank 1981).

Evaporation Ponds

Birds present on the TLDD evaporation ponds were censused from the ground during October 1982 - April 1983 and September 1983 - mid-March 1984. Ten surveys were conducted randomly throughout the first season. During the second season, one census per week was conducted during the hunting season (mid-October to mid-January) and twice weekly the rest of the field season. Surveys were conducted from a vehicle and birds were enumerated and identified with the aid of a 20X spotting scope. Large flocks (> 500) were estimated by counting a subgroup of a 100 birds and using the size of the subgroup as a basis to estimate the total number of birds in the group.

The 18 evaporation ponds represented a range of salinity (10,000 - 300,000 umhos/cm^2 EC). Nine ponds, chosen for intensive study, were grouped into 3 salinity ranges: low, 16,300 - 31,050; medium, 32,000 - 55,000; and high, 56,000 - 83,800. These 9 ponds were used in a concurrent study of invertebrate communities (Euliss, 1989). In that study, aquatic invertebrates were quantified from each pond at 3 week intervals along with a variety of chemical and physical limnological parameters: salinity, turbidity, water depth and temperature.

On the 9 intensively studied ponds, waterfowl and shorebirds were counted at dawn (or when fog lifted) and just before dusk; each survey lasted approximately 2 hours. Birds on the other 9 ponds were counted once during midday. Date, time, precipitation, cloud cover, and wind speed and direction were recorded when each pond was surveyed.

The 9 intensively studied ponds occurred in two groups (3 and 6 ponds) 5 km apart. Counts started alternately on the 2 groups of ponds. Within each group of ponds, counts were started at a randomly selected pond but proceeded in a standard sequence based on salinity. Morning and afternoon counts began at the same pond and proceeded in the same sequence for any given day. The 9 ponds sampled during midday were censused in a similar manner. During the winter of 1983-84, ducks were counted once at night and twice on hunt days.

Analysis

Discriminant and canonical correlation analysis were used to evaluate the effects of limnological parameters on abundance and distribution of waterfowl on evaporation ponds. Effect of electrical conductivity on usage of ponds by ducks was assessed with ANOVA. Analyses were conducted with SAS microcomputer programs (SAS Institute Inc. 1985).

Because the distribution of the number of ducks per pond was highly skewed (mostly none or few, occasionally very abundant) discriminant analysis was used to evaluate variables associated with presence or absence of birds on the TLDD evaporation ponds. Birds were seldom entirely absent from ponds and two categories were created (few, many) as an approximation of presence or absence of individuals of a species. Histograms of each species were utilized to select a separation point for the two categories; the separation point for the "absent" and present categories varied from 1 to 10 for the 6 species analyzed. To assess whether "few" individuals was a useful indicator of no individuals, discriminant analyses on groups of none and "many" were compared with analyses on groups of "few" and "many". These comparisons revealed no differences between the two sets of groups and to maximize sample sizes the "few" and "many" categories were used to represent presence and absence groups. Variables that contributed significantly ($\underline{P} < 0.01$) to the discriminant function, based on the univariate F, were ranked according to their R^2. Each species was examined separately and only species with $\geq$ 10 observations in each category were subjected to discriminant analysis.

Canonical correlation was used to search for relationships between the two sets of variables (ducks and invertebrates/pond characteristics); this analysis examined all species of ducks and all pond characteristics, simultaneously. Significant canonical variates had a $\underline{P} < 0.018$ for the first year and $\underline{P} < 0.0001$ for the second year. The canonical variates were described using the 2 - 4 variables with the highest correlation to the variate.

IV. RESULTS

Tulare Lake Basin

Distribution of ducks

From 20,000 to 300,000 ducks used the TLB during the study, with peak numbers of ducks occurring in mid-winter (late November - early December) (Table 1). The most abundant species (based on total number of individuals throughout both seasons) were northern pintails (58%), northern shovelers (17%), green-winged teal (14%), and ruddy ducks (5%) (Tables 2 - 5). Other ducks present for part or all of the field seasons included: American wigeon (*Anas americana*) (2%), mallard (*Anas platyrhynchos*) (2%), Cinnamon teal (*Anas cyanoptera*) (1%), gadwall (*Anas strepera*) (<1%), canvasback (*Aythya valisineria*) (<1%), and redhead (*Aythya americana*) (<1%).

The average percent of each wetland habitat present in the basin during the 2 years was: floodwater (83%), evaporation ponds (5%), duck clubs (4%), irrigated fields (4%), refuges (3%), an oxidation pond (< 0.5%) and a recreational lake (< 0.5%). The floodwater, refuges and lake (87%, combined) constituted the freshwater habitat (Table 6).

Over the two seasons, freshwater habitats supported the largest number of ducks (Table 1), but also were the largest area of wetland habitat in the TLB (Table 6). Floodwater was distributed among 6 units but there was little selection amongst the units by wintering ducks (Table 7).

Table 1. Percent of ducks observed during aerial censuses in 5 habitats in the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	53575	4	22	33	35	6	100
	Nov 12	161310	30	24	1	43	2	100
	Nov 23	124445	61	6	4	27	2	100
	Dec 6	296530	88	1	1	9	1	100
1983	Jan 18	88015	72	8	17	3		100
	Feb 1	275455	85	1	11	tr	3	100
	Sep 22	41610	27	19	22	32		100
	Oct 18	47100	76	2	9	12	1	100
	Nov 1	69865	68	3	7	22		100
	Nov 15	83685	68	4	21	2	5	100
	Nov 29	105755	92	5	3	0		100
	Dec 22	87390	73	3	20	2	2	100
1984	Jan 9	83005	80	3	5	11	1	100
	Feb 29	40996	62	5	21	7	5	100
	Apr 1	19392	54	23	13	2	8	100
Total/Mean		1578128	70	6	9	13	2	100

tr < 0.5%.

Table 2. Percent of pintails observed on 5 wetland habitats during aerial censuses of the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	18450	2	6	39	52	1	100
	Nov 12	121905	32	23	1	44	0	100
	Nov 23	100240	64	1	4	30	1	100
	Dec 6	201340	92	0	tr	8	0	100
1983	Jan 18	30920	83	3	8	6		100
	Feb 1	151450	85	tr	12	tr	3	100
	Sep 22	23045	19	4	26	51		100
	Oct 18	29440	81	tr	9	10	0	100
	Nov 1	40995	64	1	9	26		100
	Nov 15	43385	71	tr	26	2	1	100
	Nov 29	59710	97	1	2	0		100
	Dec 22	39860	78	1	19	2	tr	100
1984	Jan 9	42215	81	tr	3	16	tr	100
	Feb 29	8380	59	tr	14	23	4	100
	Apr 1	2045	72	12	1	10	5	100
Total/Mean		913380	72	4	7	16	1	100

tr < 0.5%.

Table 3. Percent of shovelers observed on 5 wetland habitats during aerial censuses of the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	15190	1	35	12	46	6	100
	Nov 12	21645	14	21	2	62	1	100
	Nov 23	7125	37	9	17	34	3	100
	Dec 6	30490	65	1	4	29	1	100
1983	Jan 18	23810	84	11	3	2		100
	Feb 1	67170	92	tr	7	0	1	100
	Sep 22	8660	24	69	2	5		100
	Oct 18	8955	52	5	17	25	1	100
	Nov 1	13255	63	3	2	32		100
	Nov 15	7190	67	7	8	10	8	100
	Nov 29	16290	90	7	3	0		100
	Dec 22	14170	77	6	15	1	1	100
1984	Jan 9	14885	71	7	11	11	tr	100
	Feb 29	13505	74	3	19	2	2	100
	Apr 1	6625	50	25	17	2	6	100
Total/Mean		268965	66	9	8	16	1	100

tr < 0.5%.

Table 4. Percent of green-winged teal observed on 5 wetland habitats during aerial censuses of the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	7520	9	tr	90	1	0	100
	Nov 12	5170	83	13	4	0	0	100
	Nov 23	7515	73	19	3	5	0	100
	Dec 6	47230	98	0	1	1	tr	100
1983	Jan 18	26015	55	0	45	tr		100
	Feb 1	32975	84	tr	15	0	1	100
	Sep 22	5260	35	0	48	17		100
	Oct 18	5390	97	tr	3	tr	0	100
	Nov 1	7955	91	0	7	2		100
	Nov 15	14430	70	0	30	0	0	100
	Nov 29	22610	98	tr	2	0		100
	Dec 22	17795	65	0	35	tr	tr	100
1984	Jan 9	13455	95	0	5	tr	0	100
	Feb 29	1980	47	tr	51	2	0	100
	Apr 1	2145	83	2	15	tr	0	100
Total/Mean		217445	79	1	19	1	tr	100

tr < 0.5%.

Table 5. Percent of ruddy ducks observed on 5 wetland habitats during aerial censuses of the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	8785	4	57	1	18	20	100
	Nov 12	6605	6	54	3	0	37	100
	Nov 23	5405	2	87	2	0	9	100
	Dec 6	6230	24	60	2	tr	14	100
1983	Jan 18	3760	1	96	0	3		100
	Feb 1	10920	57	19	3	0	21	100
	Sep 22	1915	40	55	5	0		100
	Oct 18	935	13	36	4	0	47	100
	Nov 1	1490	8	83	2	7		100
	Nov 15	6050	9	34	3	4	50	100
	Nov 29	3945	14	83	3	0		100
	Dec 22	5480	33	28	4	1	34	100
1984	Jan 9	4350	31	36	4	12	17	100
	Feb 29	3015	8	41	13	tr	38	100
	Apr 1	3037	4	66	15	0	15	100
Total/Mean		71922	20	51	4	4	21	100

tr < 0.5%.

Table 6. Percent of 5 wetland habitats present during aerial censuses in the Tulare Lake Basin, California, during the winters of 1982-83 and 1983-84.

Year	Month	N (Ha)	Fresh-water	Evaporation ponds	Duck clubs	Irr-igation	Oxidation pond	Total
1982	Oct 21	8107	35	15	7	42	1	100
	Nov 12	5884	59	20	10	10	1	100
	Nov 23	7630	71	16	8	4	1	100
	Dec 6	9532	64	13	6	16	1	100
1983	Jan 18	7961	61	17	6	16		100
	Feb 1	15482	86	9	2	2	1	100
	Sep 22	44615	93	3	2	2		100
	Oct 18	44224	91	3	3	3	tr	100
	Nov 1	14028	71	10	10	9		100
	Nov 15	44524	91	3	3	3	tr	100
	Nov 29	41377	92	4	3	1		100
	Dec 22	44913	90	3	4	3	tr	100
1984	Jan 9	44095	89	3	4	4	tr	100
	Feb 29	43594	93	3	3	1	tr	100
	Apr 1	43514	93	3	3	1	tr	100
Total/Mean		419480	87	5	4	4	tr	100

tr < 0.5%.

Table 7. Mean number of ducks per hectare on the 6 units of floodwater in the Tulare Lake Basin, California, 1982-84. Preference (rank) of values with the same superscript within a column were not significantly different ($\underline{P} > 0.05$). Preference analyized according to Johnson (1980).

Habitat	Pintail	Shoveler	Green-winged Teal	Total Ducks
Hacienda	19^{a}	6^{a}	4^{ab}	31^{a}
Alpaugh	3^{a}	1^{a}	1^{a}	4^{a}
Creight Ranch	2^{a}	tr^{a}	1^{ab}	4^{a}
South Wilbur	1^{a}	tr^{a}	tr^{b}	2^{a}
Buena Vista Lake	1^{a}	tr^{b}	tr^{c}	1^{b}
Tulare Lake	tr^{a}	tr^{b}	tr^{c}	tr^{b}

tr < 0.5.

Early in both seasons most (32-35%) ducks were present in irrigated fields, and thereafter on freshwater. In the first season (1982-83), the fewest ducks were counted in October (53,600) and the most in December (296,500). During the second season (1983-84), the fewest ducks were counted in April 1984 (19,400) and the most in late November 1983 (105,800) (Table 1).

Strong and persistent selection and avoidance of habitats was not apparent in the analysis (Tables 7, 8, 9). Large variance in the number of ducks counted (SD = 81,722) and large differences in the area of the types of wetlands (65 ha oxidation pond to 103,580 ha of freshwater) may have obscured patterns of habitat selection (Table 6). Although the oxidation pond was preferred in some cases, it was small and harbored a small portion (2%) of the ducks in the TLB and hence was relatively unimportant to wintering ducks (Table 1).

Northern pintails were the most abundant ducks in the TLB (> 200,000 for a single census) (Table 2). They used irrigation habitat early in both seasons and freshwater habitat thereafter. Few used the evaporation ponds, except during November 1982. Pintails preferred the oxidation pond and irrigated fields and avoided the evaporation ponds when wetlands were classed on ecological criteria (Table 8). On a management scale, refuges, irrigated fields and duck clubs were preferred by pintail and evaporation ponds were least preferred (Table 9).

Northern shovelers, the second most abundant duck, used evaporation ponds at densities of 4 birds/ha in October and early November 1982 and September 1983, but used the evaporation ponds at

Table 8. Mean number of ducks per hectare on the 4 types of ecologically different wetlands in the Tulare Lake Basin, California, 1982-84. Preference (rank) of values with the same superscript within a column were not significantly different ($\underline{P}$ > 0.05). Preference analyized according to Johnson (1980).

Habitat	Pintail	Shoveler	Green-winged Teal	Total Ducks
Oxidation pond	11^{a}	5^{a}	tr^{a}	42^{a}
Irrigated fields	20^{ab}	4^{ab}	tr^{a}	25^{a}
Freshwater & Duck clubs	6^{b}	1^{b}	tr^{a}	8^{a}
Evaporation ponds	2^{c}	1^{b}	tr^{a}	6^{a}

tr < 0.5.

Table 9. Mean number of ducks per hectare on the 5 types of management strategies in the Tulare Lake Basin, California, 1982-84. Preference (rank) of values with the same superscript within a column were not significantly different ($\underline{P} > 0.05$). Preference analyized according to Johnson (1980).

Habitat	Pintail	Shoveler	Green-winged Teal	Total Ducks
National Wildlife Refuges	12^{a}	3^{a}	4^{a}	21^{a}
Irrigated fields*	12^{a}	2^{ab}	tr^{bc}	15^{ab}
Duck clubs	9^{ab}	3^{ab}	4^{ab}	17^{ab}
Floodwater	5^{b}	1^{b}	1^{c}	8^{b}
Evaporation ponds*	tr^{b}	1^{b}	tr^{c}	3^{b}

* The average number of ducks per hectare for these two habitats is different from table 8 because some flights that could be used for one analysis were not usable for the other.
tr < 0.5.

low densities (< 1 bird/ha) during the remainder of each season (Table 3). Freshwater habitats supported most shovelers in both seasons. Within the ecological classification of wetlands, shovelers preferred the oxidation pond and irrigated fields and avoided the evaporation ponds (Table 8). Within the management classification scheme, refuges, irrigated fields and duck clubs were selected for and evaporation ponds were not (Table 9).

Green-winged teal were the third most abundant duck in the TLB and reached peak abundances in December 1982 (47,230 individuals) and late November 1983 (22,610 individuals). They were most numerous on freshwater habitat and duck clubs, and seldom used the evaporation ponds (Table 4). Green-winged teal preferred refuges and duck clubs when wetlands were classed on management criteria and avoided evaporation ponds (Table 9).

Ruddy ducks (Oxyura jamaicensis), the fourth most abundant duck in the basin, never exceeded 11,000. These ducks were most abundant on evaporation ponds and the oxidation pond. Only one-fifth of the ruddy ducks in the basin used freshwater habitat (Table 5).

Evaporation Ponds

An average of 4,870 ducks used the TLDD evaporation ponds daily (Table 10). Ruddy ducks were the most numerous and the only duck that consistently used these ponds. Other ducks that used the ponds included shoveler, pintail, American wigeon, lesser scaup (Aythya affinis), canvasback, redhead, cinnamon teal and green-winged teal.

Table 10. Mean number of ducks observed per day on the Tulare Lake Drainage District (TLDD) evaporation ponds, California, 1982-84.

Year	Month	N days	Pintail	Shoveler	Ruddy duck	Other ducks	Total
1982	Dec	3	80	204	4373	12	4669
1983	Jan	4	439	1177	3262	56	4934
	Feb	1	1010	2609	2423	44	6086
	Mar	2	9	2	4781	149	4941
	Apr	1	34	18	7175	277	7504
	Sep	7	49	3326	1205	22	4602
	Oct	7	1	538	2643	21	3203
	Nov	4	1	1437	4405	23	5866
	Dec	3	1	161	2641	180	2983
1984	Jan	5	21	496	2797	147	3461
	Feb	9	82	78	3751	854	4765
	Mar	4	83	75	4169	1111	5438

Use of the TLDD evaporation ponds by ducks appeared to be related to EC (Table 11); the less saline the ponds were, the more ducks were observed during bi-weekly counts. When the ponds were grouped by conductivity into 3 categories, the number of all species of ducks using these groupings of ponds were significantly different ($P < 0.05$).

Discriminant analysis was used to identify variables associated with the presence of ducks. Of the 18 variables, only a few (1-8) were associated with the presence of many or few individuals of any one species of duck (Table 12); all the associations were weak ($R^2 < 0.5$). Date, water depth and temperature were the only variables consistently associated with the presence of many individuals of most species of ducks, but the relationships were usually not the same. In 3 of 7 cases, presence of many individuals was associated with early dates (winter) and in 4 cases with late dates (spring). The association of invertebrates, when they had an effect, was usually one of abundance associated with presence of many ducks. Because associations were weak and often inconsistent, further analysis was not warranted.

Ruddy ducks were the most numerous duck on the evaporation ponds both years, except during February and September 1983. The less saline the ponds were, the more ruddy ducks were observed during bi-weekly counts (Table 11). The 3 ranges of conductivity were significantly different ($P < 0.05$) with ruddy ducks. Ruddy ducks were associated with deep water (Table 12) and more were indicated the first year on ponds that were large and contained ephydrids. In

Table 11. Mean (± SE) number of ducks per pond/day using evaporation ponds of different conductivity ranges on the Tulare Lake Drainage District (TLDD), California, 1983-84. Valves with the same superscript are not significantly different within a species.

	Conductivity (umhos/cm^2 EC) 16,300-31,050 (N=212)	32,000-55,000 (N=280)	56,000-83,800 (N=138)
Pintail	$1 \pm tr^a$	9 ± 3^b	$1 \pm tr^a$
Shoveler	40 ± 8^a	107 ± 27^b	5 ± 2^a
Ruddy duck	555 ± 38^a	79 ± 6^b	7 ± 3^c
Total ducks	619 ± 38^a	210 ± 25^b	17 ± 4^c

tr < 0.5.

Table 12. Rank order (based on R^2) of wetland variables contributing significantly (univariate F, $\underline{P} \leq 0.01$) to discriminant functions of presence of few or many individuals of 6 species of ducks on the Tulare Lake Drainage District evaporation ponds, California, during the winters of 1982-83 (1) and 1983-84 (2). The relative value of each variable is indicated by > (more) or < (less).

Variable	Pintail		Green-winged Teal		Shoveler		Ruddy duck		Cinnamon Teal		Lesser Scaup	
	1	2	1	2	1	2	1	2	1	2	1	2
Date[a]	<1	>4	<1		<1				>2	>3	>2	
Water depth	<2	<3	<2		<3		>1	>4	>5	<8	>4	
Temperature	<3		<3		<2				>4		>3	
Notonectid	>4		>4			>1						
Epphia, Water Column	>5											
Ephydridae		>1								>4		
Turbidity[b]		>2						>6		>2		
Ostracoda				>1						>7		>3
Copepods				>2	>5				>1	>1	>5	>2
Corixid					>4					<6		
Corixid egg					>6		>3	<2				
Total Benthic							>2	<5				
Chironomid							>4	>3			>1	
Salinity (umhos/cm^2)								<1				
Oligochaete										>5		
Libellulide												>1
Total Seeds									>3			

[a]date > = later in the season.
[b]Turbidity < = clearer water.

the second field season, more ruddy ducks were expected on ponds with low salinity and abundant chironomids (Tanypus grodhausi); size of pond was unimportant (Table 13).

Northern shovelers occurred in large flocks (> 1,000) in January, February, September, and November 1983 (Table 10). Northern shovelers were found on ponds of medium salinity concentrations (32,000 - 55,000 umhos/cm^2 EC) in significantly greater numbers than on ponds of either higher or lower salinity (Table 11). They were associated with shallow water (Table 12) and were expected early in the second season in ponds with many epphia and corixides (Trichocorixa reticulata) (Table 13).

Northern pintails were uncommon on the evaporation ponds (< 100) except in February 1983 when they occurred in large numbers (> 1000) (Table 10). Northern pintails were found on ponds of medium salinity (32,000 - 55,000 umhos/cm^2 EC) in significantly greater numbers than on ponds of either higher or lower salinity (Table 11). They were associated with shallow water (Table 12), and in the second season, were associated with ponds containing many ephydrids (Table 13).

American wigeon were observed in large flocks in February and March 1984 (up to 1100 birds daily) on one pond having an abundant growth of widgeongrass (Ruppia maritima).

The strongest canonical correlation (I) for the 1982-83 season indicated an association of redheads, canvasbacks and scaup in ponds with many chironomids. Redheads were associated with deeper ponds, earlier in the second season (Table 13). Scaup were associated with

Table 13. Canonical correlation of the Tulare Lake Drainage District evaporation ponds, California, from December 1982 - March 1984.

Canonical Correlation	Birds	Invertebrates & Pond Characteristics
1982-83		
I	Canvasback	Chironomidae
	Scaup	
	Redhead	
II	Ruddy duck	Hectare (Larger)
		Ephydridae
		Depth (Deeper)
1983-84		
I	Ruddy duck	Salinity (Lower)
		Depth (Deeper)
		Chironomidae
II	Pintail	Ephydridae
III	Cinnamon teal	Copepoda
IV	Shoveler	Epphia benthic
		Date (Earlier)
		Epphia water column
		Corixidae
V	Redhead	Depth (Deeper)
		Date (Earlier)

deep water (Table 12). In the second season, Cinnamon teal occurred in association with copepoda (Table 13).

Other physical factors affecting use of evaporation ponds

On waterfowl hunt days, more ducks ($\bar{x}$ = 361 $\pm$ 76 / pond, n = 54) were present on the evaporation ponds compared to the number present on the nearest non-hunt day on which counts were conducted ($\bar{x}$ = 229 $\pm$ 46 / pond, n = 54). On hunt days, ducks congregated in large flocks (500 - 3500) on only a few ponds that had the lowest salinity. These ponds had significantly (P < 0.05) more birds ($\bar{x}$ = 958 $\pm$ 211 / pond) on hunt days than the other ponds ($\bar{x}$ = 153 $\pm$ 32 / pond). On hunt days, pintails and shovelers were present in greater numbers than on non-hunt days (5% and 36%, respectively, on hunt days, 0.3% and 27% on non-hunt days) based on total number of ducks using the ponds.

The 2 series of evaporation ponds were 2 and 7 km respectively, from Kern NWR, where hunting occurred on Saturdays, Sundays, and Wednesdays. While the evaporation ponds were open to hunting, few people hunted them probably because of the large size of the ponds ($\bar{x}$ = 65 ha) and the lack of emergent vegetation and other structures where hunters could conceal themselves. Evaporation ponds apparently serve as sanctuary for ducks on days when nearly all other wetlands in the TLB were being hunted, but this conclusion must be tentative because of the small sample size (only 2 counts conducted on hunt days).

One count at night revealed few ducks ($\bar{x}$ = 34 $\pm$ 28 / pond) on the evaporation ponds; 98% of these were ruddy ducks. The spotlight was not strong enough to illuminate the entire pond, and this count can not be compared directly with diurnal counts. Although the ducks that were observed did not appear disturbed by the spotlighting, some ducks may have taken flight before being illuminated and hence were undetected. The evaporation ponds lacked the characteristics of nocturnal feeding cover described by Tamisier (1981) and therefore may not have been attractive to ducks at night.

V. DISCUSSION

Freshwater wetlands were the most frequently used habitat types in the TLB by wintering ducks during my study. I found that the managed wetlands on refuges and duck clubs were most preferred by ducks. However, different species of waterfowl made differential use of habitat that reflect species specific habitat requirements (Weller 1964, Chabreck 1979).

Shovelers and pintails were similar and preferred refuges, duck clubs, and, in the fall, irrigated fields. Irrigated fields were especially attractive to pintails and shovelers, but were present for only short periods of time (water is present for only about 2 weeks on a field), in small amounts ($\bar{x}$ = 1055 ha), and were restricted principally to fall and spring. Duck clubs were flooded during the hunting season (late October to mid-January) whereas refuges were flooded during most of the wintering period. These three types of wetlands were preferred habitats of shovelers and pintails, supported large numbers of birds, and were present during most of the wintering period.

Floodwater was not preferred by shovelers and pintails but provided habitat for large numbers of birds. Floodwater was the largest wetland type in the TLB (16X larger than the next largest, evaporation ponds) and supported the largest number of pintails (49%) and shovelers (51%). However, density of pintail (50/100ha) and shovelers (15/100ha) was lower on floodwater than in other habitats, suggesting that it was of lower quality then most other habitats in the TLB. Of all the wetlands important to shovelers and pintails in my study, floodwater was the most persistent.

Ruddy ducks preferred permanent wetlands in the TLB, especially evaporation ponds where about half the ruddy ducks present were censused. Ruddy ducks rarely used irrigated fields or duck clubs; use of freshwater habitat was consistent but occurred at lower densities than on evaporation ponds.

Evaporation ponds appeared to satisfy the needs of ruddy ducks during winter. Ruddy ducks were fairly sedentary during winter and made extensive use of wetlands that provide food and shelter. Ruddy ducks fed extensively on corixids and chironomids on TLDD evaporation ponds, both of which were very abundant (corixid $\bar{x} = 0.354$ g dry weight/m^2; chironimids $\bar{x} = 0.405$ g dry weight/m^2) (Euliss 1989). However, evaporation ponds produced few other waterfowl foods in abundance and I was unable to establish consistent relationships between use of ponds by ducks and invertebrate populations and pond characteristics, except for ruddy ducks. Shovelers and pintails may make extensive use of evaporation ponds during occasional blooms of corixids (Euliss 1989) but evaporation ponds do not appear to be principal feeding sites for most species of ducks in the TLB. Evaporation ponds do not provide densely vegetated emergent habitats that pintail and green-winged teal utilize for nocturnal foraging (Tamisier 1976, Euliss 1984). I found few ducks other than ruddy ducks on evaporation ponds at night which also supports my conclusion that evaporation ponds were not attractive feeding sites. Use of evaporation ponds by large numbers of ducks on hunt days does indicate that the ponds provide sanctuary. Almost all other wetlands in the TLB are hunted 3 days/week and there may be insufficient sanctuary available.

Evaporation ponds provide good foraging and resting habitat for ruddy ducks, but they are of marginal value to other ducks, although they may provide sanctuary during the hunting season. However, water quality in evaporation ponds may be problematic due to accumulation of salts and other compounds from agricultural soils. Evaporation ponds in the TLB are known to contain heavy metals (Presser and Barnes 1985), especially selenium which has been associated with embryonic mortality and deformity in waterbirds (Ohlendorf et al. 1986a, 1986b, 1987).

The distribution and numbers of ducks I observed may have been considerably different without the extensive floodwater available due to the 1982 flood. The mean number of ducks in the TLB in the year before (1981-82) ($\bar{x}$ = 70,307 ducks/month) and after my study (1984-85) ($\bar{x}$ = 38,399 ducks/month) (Kern National Wildlife Refuge unpubl. data) were lower than during the 2 years of the study (171,291 and 57,991 ducks/month, respectively).

When the TLB was first flooded in December 1982, ducks made extensive use of the areas inundated (31 ducks/ha). Floodwater was still present in the TLB the second field season, but fewer ducks (< 3 ducks/ha) utilized them. Initial flooding of the area enhanced the availability of duck foods (terrestrial seeds and invertebrates) as agricultural fields were inundated. In areas where flood water persisted until 1983-84, food supplies were probably limited because chronic flooding restricted food supplies to a few pioneering hydroponics and aquatic invertebrates.

There were large areas of floodwater during my field seasons that served the daytime needs of ducks in the TLB, but during most years, evaporation ponds would be the main source of open water available to ducks. Observations made by other workers suggest that evaporation ponds were used more by ducks during years when less alternate freshwater habitat was available (Euliss pers. comm.) and fewer ducks were present in the TLB.

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VII. APPENDICES

Appendix 1. Means of characters that significantly discriminated between presence of many or few ducks on the Tulare Lake Drainage District evaportion ponds, California, 1982-1984.

	Pintails				Green-winged Teal			
	1982-83		1983-84		1982-83		1983-84	
	<10	≥10	<10	≥10	<10	≥10	<2	≥2
N (ponds)	120	22	502	32	129	13	520	14
Date	2/16/83	1/2/83	12/25/83	2/13/84	2/13/83	1/3/83		
Depth (cm)	87	50	61	38	86	40		
Temp. (°C)	16	8			15	8		
Notonectid	1.6^{-5}	1.6^{-4}			3.0^{-5}	14.0^{-5}		
Epphia, Water Col.	1.5^{-6}	5.5^{-6}						
Ephydrid			3.4^{-7}	5.3^{-5}				
Turbidity			0.20	0.31				
Ostracod							8.8^{-7}	2.0^{-4}
Copepods							9.1^{-6}	2.7^{-4}
Error Rate	0.01	0.18	0.01	0.53	0.05	0.15	0.002	0.57
Total Error	0.04		0.04		0.06		0.02	

Appendix 1. continued

	Shoveler				Ruddy Duck			
	1982-83		1983-84		1982-83		1983-84	
	<10	≥10	<10	≥10	<10	≥10	<2	≥2
N (ponds)	103	39	378	156	39	106	176	358
Date	2/22/83	1/7/83						
Depth (cm)	87	67			60	90	51	64
Temp. (°C)	17	9.5						
Notonectid (n)			5.0^{-4}	0				
Turbidity							0.17	0.22
Copepods	1.7^{-3}	1.2^{-4}						
Corixid	2.3^{-5}	7.4^{-3}						
Corixid Eggs	2.3^{-7}	6.0^{-4}			1.1^{-4}	4.4^{-4}	0.07	0.02
Total Benthic					1.5^{-4}	2.7^{-3}	3.7^{-3}	2.2^{-3}
Chironomid					4.0^{-5}	2.2^{-3}	9.5^{-5}	8.6^{-4}
Salinity (umhos/cm^2)							59	33
Error Rate	0.14	0.15	0.04	0.71	0.33	0.06	0.18	0.08
Total Error	0.14		0.24		0.13		0.11	

Appendix 1. continued

	Cinnamon Teal				Lesser Scaup			
	1982-83		1983-84		1982-83		1983-84	
	0	≥ 1	<10	≥ 10	0	≥ 1	<9	≥ 10
N (ponds)	128	17	455	79	129	16	514	20
Date	2/4/83	3/7/83	12/18/83	2/20/84	2/4/83	3/15/83		
Depth (cm)	80	101	62	46	79	109		
Temp. (°C)	14	18			14	20		
Ephydrid			6.5^{-7}	2.0^{-5}				
Turbidity			0.19	0.29				
Ostracod			0	4.0^{-5}			2.7^{-6}	9.1^{-5}
Copepods	9.8^{-4}	3.0^{-3}	1.3^{-6}	1.0^{-4}	1.0^{-3}	3.0^{-3}	1.1^{-5}	1.5^{-4}
Corixid			2.8^{-2}	2.5^{-3}				
Chironomid					8.5^{-4}	8.0^{-3}		
Oligochaete			7.7^{-8}	8.9^{-7}				
Libellulide							3.9^{-7}	1.5^{-5}
Total Seeds	2.8^{-5}	1.3^{-4}						
Error Rate	0.06	0.35	0.02	0.48	0.01	0.33	0.01	0.50
Total Error	0.10		0.09		0.03		0.03	

Appendix 2. Results of canonical correlation of numbers of ducks and characteristics of evaporation ponds, Tulare Lake Drainage District, California, December 1982 - March 1984.

Canonical Correlation	Ducks		Ponds	
	Species	Correlation	Characteristics	Correlation
1982-83				
I	Canvasbacks	0.81	Chironomids	0.92
	Scaup	0.78		
	Redhead	0.54		
II	Ruddy Duck	0.87	Size	0.62
			Ephydride	0.55
			Depth	0.48
1983-84				
I	Ruddy Duck	0.98	Salinity	-0.71
			Depth	0.62
			Chironomid	0.54
II	Pintail	0.91	Ephydride	0.90
III	Cinnamon Teal	0.96	Copepod	0.89
IV	Shoveler	0.99	Benthic Epphia	0.61
			Date	-0.41
			Water Column Epphia	0.41
			Corixidae	0.40
V	Redhead	0.98	Depth	0.40
			Date	-0.32

Appendix 3. Aggregate percent by weight of total invertebrates in the water cloumn in Tulare Lake Drainage District evaporation ponds, California, 1982-84.

Invertebrate	1982-83	1983-84
Corixid eggs	20.3	55.9
Corixidae		
Trichocorixa reticulata	24.2	39.3
Notonectidae	1.0	0.6
Berosus sp.	tr	0.1
Egg masses	0.2	0.4
Copepoda	54.1	0.4
Cladocera	tr	0
Epphia	0.1	0.1
Ostracoda	tr	0.2
Dytiscidae	0	1.0
Diptera	0	1.3
Mosquito fish		
Gambusia affinis	0	0.7
Total	100	100
Total dry weight (grams)	1.07843	5.36048

tr < 0.05%.

Appendix 4. Aggregate percent by weight of total benthic invertebrates in Tulare Lake Drainage District evaporation ponds, California, 1982-84.

Invertebrate	1982-83	1983-84
Chironomidae		
Tanypus grodhausi	84.5	39.8
Chironomus stigmaterus	3.8	0
Epphia	10.8	56.0
Ephydridae	0.9	3.0
Libellulidae	0	0.9
Oligochaetes	0	0.2
Diptera misc.	0	0.1
Total	100	100
Total dry weight (grams)	0.10703	0.11515

tr < 0.05%.